Discovery Through Situational Awareness

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Project Scope

Work is being performed under the DOE GMLC (Grid Modernization Laboratory Consortium) program

Create a tool that applies statistical and machine-learning algorithms in context of big data analytics to investigate and implement anomaly and event detection algorithms in near real-time

Current Focus

- Working with the Eastern Interconnect
- Initial focus on phase angle pair analyses
- Provide the EI partners with a frequent (i.e. daily or weekly) report of the findings
Power Grid Statistical Analytics: Our Historical Journey

- Aircraft safety Morning Report w/ NASA
- Analytics Using State Estimator Data w/ EI
- Data Investigations Using PMU Data (uncovering data quality issues, etc.)
- DISAT
- GMLC and Beyond
  - Machine learning basis
  - Many additional data streams
  - Predictive analytics
- Data Integrity Situational Awareness Tool (PMU Data Analytics w/ BPA)
Pre-Processing Steps

- Read raw Phasor Measurement Unit (PMU) data
- Develop and then use data quality filters to clean poor quality data

1 day of 60 Hz PMU data (54 PMUs) = 26 GB
Feature Extraction (Data Signatures)

- Regression fits through the data calculate estimates of value, slope, curvature (acceleration), and noise.
- Can be calculated in the presence of missing or data quality flagged values.
- Summaries of these features are used in the analyses.
Multivariate Baselining

Baseline captures what normal behavior is expected to be

- Group similar behavior
  - **Time periods** that group together indicate normal grid behavior
  - **Variables** that group together indicate highly correlated variables and may be candidates for feature reduction

- Identify data that does not belong with the normal behavior
  - **Time period** contains data that is unusual (possible abnormal grid behavior)
  - **Variable** is unlike other variables, or something has happened to indicate a behavioral change in the variable
Creating a Baseline – Unsupervised Learning

- Training Data: Historical PMU Data
- Real Time PMU Data
- Baselining Learning Algorithm
- Model
- Class 1
- Class 2
- Class 3
- Class 4
- Class 5
Identifying Data Driven Atypical Events

Using multivariate statistical techniques to establish baselines of typical behavior, atypical moments in time can be discovered and the variables responsible can be identified.
Recent Atypicality Example

- Processed 8 months of PMU data (15 PMUs)
- Focused on phase angle pairs
- Spatial plot showing phase angle pairs (red means contributing to the atypicality)
Unsupervised learning (clustering) used to determine which variables are most similar during Time Period A.

Proximity on tree indicates similarity
Phase Angle Pair #2 is no longer like Pair #1. Why?
Supervised Learning

Training Data: Historical PMU Data

Real Time PMU Data

Baselining Learning Algorithm

Predictive Model

Class 1
Class 2
Class 3
Class 4
Class 5

Weather
Normal
Voltage Drop
Fault
Maintenance

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Normal
Voltage Drop
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Maintenance
A list of 199 frequency events was obtained during an 8 month time frame. The following supervised learning techniques were studied:

- DT – Decision Tree
- RF – Random Forest
- SVM – Support Vector Machine
- ANN – Neural Network
- GLM – GLM Net (Lasso)
- AB – Adaptive Boosting
- GBM – Gradient Boosting

- Sensitivity – probability of correctly identifying frequency events.
- Specificity – probability of correctly identifying non-frequency events.
Next Steps

- Put our anomaly detection and oscillation algorithms into an EPG prototypical tool to be used on Eastern Interconnect PMU Data
  - Review findings and tune algorithms
- Continue machine learning approach to find events and patterns, including other power grid data and other data streams like weather, social media, etc.
- Use spatial statistical techniques to take advantage of spatial relationships
- Apply predictive analytics

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